Performance of low cost photodiodes in nuclear spectroscopy

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Introduction

Recently, there have been attempts all over the world to design and develop low cost, rugged nuclear radiation detection devices and bring them to the reach of common man [1]. Low-cost si-pin diodes, photo -diodes and similar low cost devices are utilized as radiation detectors in medical diagnostic machines involving nuclear radiation, security services, surveillance etc. However, small teaching labs and universities with modest funds usually cannot afford to set up nuclear physics experiments in the courses due to their high cost and regular maintenance issues.

Table 1: Dark current of different diodes.

Name	Sensitive area (mm^{2})	Dark Current At Reverse Voltage (V)	Dark Current nA
BPW34	7. 5	10	2-30
BPW21	7.5	5	2-30
VTB8440BH	5.16	2	2
BEL	25	70	2

A photodiode useful for nuclear radiation detection should have its capacitance low, which decreases with increasing reverse bias. However, with increase in reverse bias the leakage / dark current increases. So to select the optimum operating reverse voltage, we need to measure the capacitance and leakage current as a function of increasing reverse bias. The low capacitances of these detectors demand usage of exactly matching preamplifiers which we are trying to develop. Reduction in the cost of data acquisition, processing and display will be other hurdles to be crossed.

Our ultimate aim is to use cheap and rugged photo – diodes to develop detector systems suitable for teaching labs. So far with conventional pre-amplifier and data acquisition system in our lab we have succeeded in using these photodiodes for charge particle detection. We are now designing low cost preamplifiers and suitable analogue to digital converters to count the number and energy of the incident radiation. These are our next objectives.

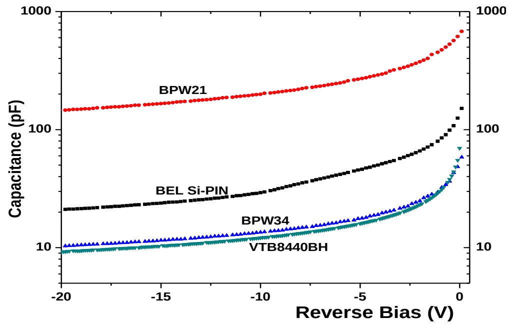

Fig. 1 Variation of capacitance with reverse bias

Experimental Details and Analysis

We have procured photodiodes from local market in Kolkata. The specific numbers of some of these diodes are VTB8440BH, BPW21, BPW34, VBPW34FASR and LED55C. We have also compared the characteristics of a 5mm×5mm Si-PIN diode from Bharat Electronics Limited (BEL) [2] with them.

- *Testing for light detection*

To start with we have tested the diodes with continuous and blinking white light to test their responses. A simple circuit for generating blinking of the light source at different frequencies was designed and used for this purpose. We found that VTB8440BH gives the best performance in terms of maximum pulse height for same intensity of light.

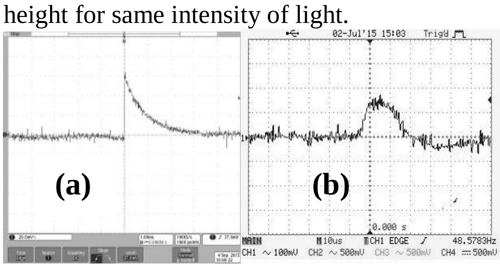

Fig. 2 Preamplifier pulses corresponding to alphas from ^{241}Am sources. (a) ~3 ms width and 60 mV height using Ortec 142B (detector VTB8440BH) (b) ~30μs width and 150 mV using a preamplifier locally fabricated (detector BPW21).

- *Measurement of C-V characteristics and dark current*

We have performed C-V measurements with an Agilent E4980A LCR meter (Fig.1). So far we have not estimated the dark current with increasing reverse bias. However, we have compared their dark currents obtained from their data sheet (Table. 1). The Si-PIN from BEL, already utilized for radiation detection by earlier workers has much better characteristics, as expected. However, our aim is to test the smaller locally available diodes.

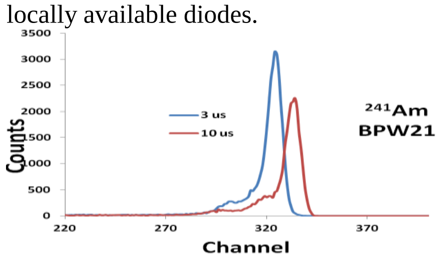

Fig. 3 Alpha spectrum obtained with BPW21

- *Testing the diodes for alpha detection with standard preamplifiers*

We have then tested these diodes for detection of alpha particles (5.483 MeV) using standard ORTEC 142B preamp with ^{241}Am as radioactive source without any reverse bias. The preamplifier pulse is shown in Fig 2a for VTB8440BH. The preamplifier output later has been amplified with an ORTEC 672 spectroscopic amplifier with 3 and 10 μs shaping times (Fig 3) for a BPW21 diode. The spectrum is shown in Fig.3 for 0V reverse bias.

- *Testing the diodes for alpha detection with locally fabricated preamplifiers*

The proper matching between detector and preamplifier is essential for low noise of the spectroscopy system. We have initiated fabrication of suitable preamplifier [3] in our laboratory and testing their performances. A representative preamplifier pulse is shown in Fig 2b. It is evident that we still need to work further in this direction.

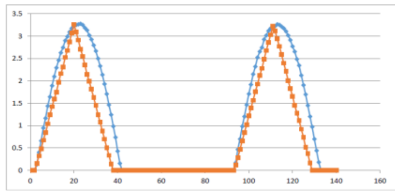

Fig. 4 The digitized outputs corresponding to sine and triangular waves.

- *Testing an 8 bit ADC and Raspberry Pi for data acquisition*

We have coupled a PCF8591 [4], an 8-bit analog-to-digital conversion to Raspberry Pi 2 (a credit-card sized single-board computer [5]) to understand and test digitization of input signals. We provided inputs from a signal generator and could successfully digitize and distinguish a triangular wave from a sine wave (Fig. 4). We are yet to test digitization of preamplifier signals from the radiation detectors.

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